… CEMENT AND LIME
MANUFACTURE

PUBLISHED 20TH OF EACH MONTH. PRICE 1/- A COPY. ANNUAL SUBSCRIPTION 12/- POST FREE

PUBLISHED BY
CONCRETE PUBLICATIONS LIMITED
14 DARTMOUTH STREET, LONDON, S.W.1
TELEPHONE: WHITEHALL 4581.
TELEGRAPHIC ADDRESS:
CONCRETIUS, PARL, LONDON

PUBLISHERS OF
"CONCRETE & CONSTRUCTIONAL ENGINEERING"
"CONCRETE BUILDING & CONCRETE PRODUCTS"
"CEMENT & LIME MANUFACTURE"
"THE CONCRETE YEAR BOOK"
"CONCRETE SERIES" BOOKS, ETC.

VOLUME XVI. NUMBER 5 MAY 1943

# Conveying and Elevating in the Cement Industry.

THE mechanical efficiency of conveyors and elevators is, and always will be, low; but, although the over-all efficiency of any complete manufacturing plant may be lower than 50 per cent., a reduction in the losses of the auxiliaries will help to improve this figure. If the plant is on a sloping site it may be possible to avoid the use of some elevators, or even conveyors, but care must be taken to ensure that their omission results in a real as well as an apparent advantage. A good lay-out, with the promise of continuous operation, must always be the aim, and any reasonable number of auxiliaries will be justified if this object is attained.

The efficiency of conveyors and elevators is determined, or largely influenced, by the selection of the type of unit. If the type is correct and the details of construction good, and if the unit is run continuously, its efficiency should be as high as is practicable; but if the type is unsuitable the efficiency will be low, no matter how good the construction details—wrong selection may result in erratic running, and this is one of the worst possibilities that may arise. Elevators are much less popular now than they were, and it has become usual to replace them with belt conveyors. This change is possibly owing to the trouble that elevators have given, especially when their capacity has been large. Large capacity and considerable height of lift are searching conditions for elevators, and only those of best design and construction will meet such conditions. Moreover, elevators of large capacity are costly to install, and they have a large number of wearing parts. Elevators of large capacity for use on very lumpy or very dusty materials should be avoided if possible, even if this involves an increase in capital cost and increasing the area of the plant; this condition, however, will not apply to elevators of small capacity dealing with suitable material. Con-

sideration will now be given to a number of selected duties and the type of machine that best meets the conditions involved.

### Quarried Stone.

For run-of-quarry stone having a maximum dimension of, say, 9 in. cube, and a maximum weight per piece of 80 lb. to 90 lb., wagons or trucks or their equivalent should be used. A wide conveyor belt, having troughed idlers, might be practicable, under the best conditions of speed and feed, but the risk of the belt being damaged or cut by the large pieces of stone is very real and rules it out for this duty. If the site or other conditions demand a belt, the stone should first be crushed to a maximum size of 3 in. to 4 in. cube; a belt could then be used with but small risk, and the stone could be fed on the belt as it leaves the crusher. The stone from the quarry should be tipped into the crusher hopper direct. The feed from the hopper could be extracted, and the crusher fed at a constant rate, by a feeder of either the bar type, the drop-bar type, or the hanging-chain type; either of these types would be generally suitable, but one or the other would be the best. The efficiency of the types would be similar, but the hanging-chain type would call for the least power; the power required, however, would be small.

### Crushed Stone.

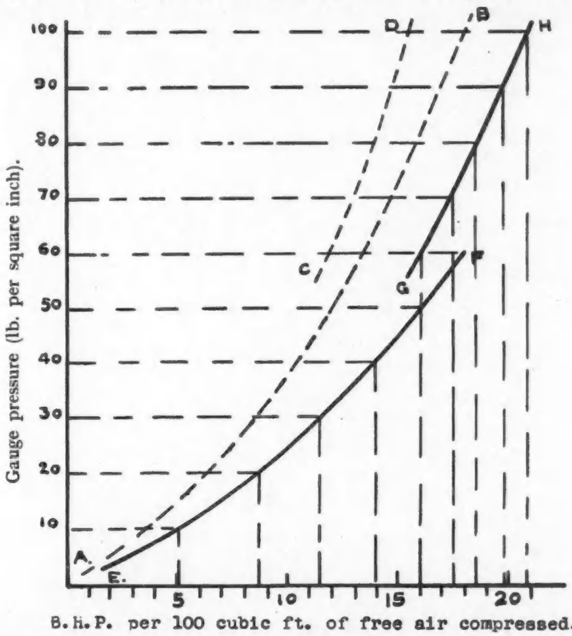
If the conveyor that deals with the crusher discharge were of the belt type, it should be troughed to ensure the least amount of spilled material. For relatively short lengths the speed could be, say, 250 ft. to 300 ft. per minute, while if the length were considerable the speed might be, say, 400 ft. to 450 ft. per minute; the higher speed would call for precise feeding to avoid splashing as the material is fed on to the belt. If a quantity of smalls or fines were produced in the process of crushing, it would be an ideal material for conveyance by belt, but if the product were "nutty" it would not be so good. Moreover, a nutty product could not be dealt with satisfactorily by an elevator owing to its size, but the conveyor discharge could to advantage become the feed for any secondary crusher necessary for mill-feed purposes.

The discharge from the secondary crusher should have a maximum dimension of, say, ½ in. with a large quantity of fines; this product could be conveniently dealt with by either a belt conveyor or bucket elevator to the mill-feed hopper. The mill feed would be extracted from the hopper by a band conveyor of the "cubimeter" type, but a good fairway opening would be necessary and the conveyor should be equipped with a variable-speed drive. If the outlet from the hopper were of correct construction the amount of material on the belt and the volume of stone discharged would be reasonably constant, and the amount of mill feed would be determined by the speed of the belt.

### Slurry.

The mill product should be fine enough to be dealt with by a pump of the centrifugal type. Some of these pumps are lined throughout with rubber, while others are lined with white iron and fitted with an easily-renewable white iron

impeller. Generally the mill discharge is unsuitable for handling with ram pumps owing to the cutting nature of the grit and the resultant wear that would take place. The efficiency of the centrifugal pump is low owing to the large clearance necessary; it may possibly be as low as 30 per cent. or 35 per cent., but low capital cost and the ease with which replacement parts can be fitted are in its favour. The glands must be arranged so that they are isolated from the grit, and this, in conjunction with the general design of the pump, imposes a limit, or has an influence upon, the head against which the pump will discharge. The efficiency of the ram pump would also be low owing to the need for tight




Curves AB and CD indicate the power required under adiabatic conditions assuming there were no losses of any kind in the compressing process. Curves EF and GH indicate the actual power that would be necessary assuming an overall compressing efficiency of 74 to 75 per cent.

**Fig. 1.—Power Required for Compression.**

glands—which are of large diameter—to ensure the tightness of the packing. The efficiency of the two types of pump may therefore be considered as substantially the same under similar conditions.

Another type of slurry lifter is the pressure-air displacement unit, comprising either one or two high-pressure slurry containers and an air compressor. The slurry, as produced, flows into one or other of two containers and when this container is full the incoming slurry is turned into the other container; in the meantime, air has been turned into the first container and the slurry

discharged upwards or through a pipe of any desired length. By using two containers the flow of slurry from the mill may remain continuous although discharge from the containers is intermittent. An advantage would result if the discharge from the containers were rapid, as the pause that occurs at the moment the container becomes empty provides an amount of breathing time which, under some conditions, may be an advantage. With this system the slurry is prevented from coming into contact with the working parts of the machinery and no wear results. It is possible, however, that the containers will require washing out occasionally to prevent the thickened slurry building up on the inside surfaces.

A comparison of the power required by the two systems when dealing with the slurry produced by washing or grinding, say, 100 tons of dry limestone per hour to a moisture content of, say, 38 per cent. and discharging it against a pressure of 100 lb. per square inch is as follows.

One hundred tons of dry stone ground wet with a moisture content of 38 per cent. weighs :

| | |
|---|---|
| Stone .. .. .. .. .. .. .. | 100 tons |
| Water .. .. .. .. .. .. .. | 62 ,, |
| Total .. .. .. | 162 ,, |

The volume of the slurry would be :

$$\text{Stone} \quad \frac{100 \times 2{,}240}{160} = 1{,}400 \text{ cu. ft.}$$

$$\text{Water} \quad \frac{62 \times 2{,}240}{62{\cdot}5} = 2{,}200 \text{ ,,}$$

$$\text{Total} \quad 3{,}600 \text{ ,,}$$

$$\text{Volume of slurry per minute} = \frac{3{,}600}{60} = 60 \text{ cu. ft.}$$

$$\text{Weight of slurry per minute} = \frac{162}{60} = 2{\cdot}7 \text{ tons}$$

$$\text{Density of the slurry mix} = \frac{2{\cdot}7 \times 2{,}240}{60} = 100 \text{ lb. per cu. ft.}$$

The net power required for pumping, whichever type of pump is used, would be

$$\frac{2{\cdot}7 \times 2{,}240 \times 100}{33{,}000} = 18{\cdot}4 \text{ H.P.}$$

With a pump efficiency of 35 per cent. the gross power required would be

$$\frac{18{\cdot}4}{0{\cdot}35} = 52{\cdot}5 \text{ B.H.P.}$$

Under pressure-air displacement conditions the volume of pressure air would be in agreement with that of the slurry the air displaced. From the foregoing

figures the slurry volume would be 60 cu. ft. per minute and this equals

$$60 \times \frac{100 + 15}{15} = 460 \text{ cu. ft. of free air per minute.}$$

An allowance for volumetric loss will increase the free air figure to, say, 500 cu. ft. per minute.

From the data given in *Fig.* 1 (reproduced from this journal for November, 1942) it will be seen that 100 cu. ft. of free air per minute compressed to a pressure of 100 lb. per square inch will require 21 B.H.P., and on this basis 500 cu. ft. will require up to 105 B.H.P. This figure—105 B.H.P.—for the air-displacement unit compares with 52·5 B.H.P. for the centrifugal type pump and the ram pump respectively; the power required for the two systems and will be referred to later.

As the output of the mill will vary from hour to hour it will not be possible to ensure that the pump discharge will always be in agreement with the mill discharge.

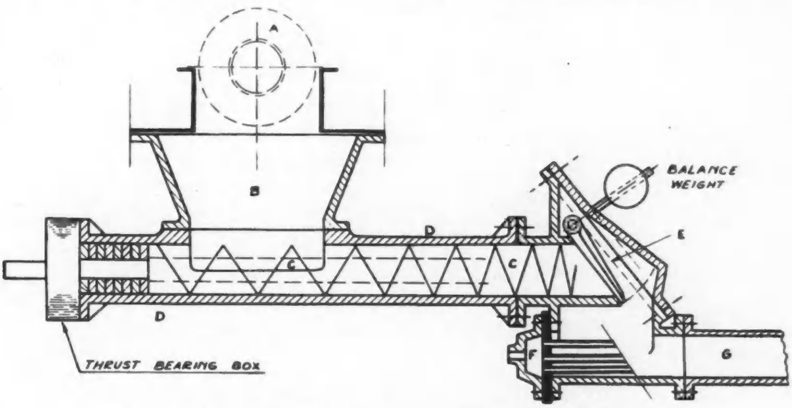



**Fig. 2.—Diagrammatic Section of Fuller-Kinyon Pump.**

As the capacity of the pump must be equal to that of the mill at its maximum, it is not unusual, when the mill output is low, for the pump attendant to "prop" up one of the section valves of the ram pump with one of the rams doing no useful work. This procedure, which reduces the efficiency of the pump considerably, is not practicable with the centrifugal-type pump, and it is not unusual to run this pump light, and usefully, intermittently. In view of these two probable conditions, the efficiency of the two pumps would be much lower than the assumed 35 per cent.

The operating condition of the pressure-air displacement unit is different, and it would be possible for automatic controls, actuated by the slurry or pressure air, to obtain a net operating time in substantial agreement with the gross time and so reduce the power loss. These comparative conditions would operate in favour of the pressure-air displacement unit, and it is possible that the power

taken by this latter unit would make it competitive with the other types. This could to advantage be tried out in practice ; in any case there would be no need for periodic overhaul with renewal of working parts.

## Clinker.

The handling of clinker is difficult owing to its initial high temperature, its abrasive nature, and the amount of dust that it contains. The temperature of clinker as discharged from most modern kilns is usually too high for handling by any of the woven or belt fabrics, and the use of these belts would result in a short working life. The best alternative is the all-metal shaker-trough conveyor, provided the trough is lined to facilitate quick renewal when wear has taken place, and provided also that ample allowance is made in the design to accommodate the increased length caused by expansion. The increases in length of a trough 100 ft. long with a temperature rise of 250 deg. F. to 300 deg. F. is about 2 in.

Gravity-type bucket elevators are also used very successfully for this duty. Temperature rise has little effect on the operation of this plant, as, although the buckets are subject to considerable rise of temperature, the chain is not. These conveyors are costly, but where the length and the height of lift are considerable the high first cost is more than justified, and they should have every consideration ; the larger the quantity of clinker to be handled the greater the justification for their adoption.

## Cement.

Under conveying conditions cement is usually aerated, dusty, and very fluid ; it must be kept perfectly dry ; splashing must be avoided at the point of feed, and the minimum disturbance must be set up at the point of discharge. Although cement will flow like water when fully aerated, it packs very densely at the bottom of deep vertical silos.

Totally-enclosed spiral conveyors were used almost universally previous to the adoption of vertical silos for storage, and when the quantities dealt with were small and the length of conveyance short ; under these conditions the spiral served a good purpose provided the joints were reasonably dust-tight. When spirals were originally adopted the cement was ground much coarser than at present and the rate of wear of the conveyor parts much more pronounced. Much of to-day's cement is ground so finely that it acts almost as a lubricant, and the rate of wear resulting from handling is very low. The greatest objections to the use of the spiral are its limited capacity and the unwieldy lengths that, under some conditions, are required to-day.

Belt conveyors are generally unsuitable for the conveyance of fine cement owing to the amount of dust caused at the point of feed and at the point of discharge. If they are adopted for the duty, it is almost necessary to enclose them completely for their full length, but the conditions that justify the use of band conveyors for fine cement are very rare.

A large amount of development work has, during late years, been done to adapt the "Redler" system for conveying cement. In this system the conveying is effected upon a square or rectangular core (say, 8 in. by 8 in. or 12 in. by 10 in.) at very low speed—10 ft. or 12 ft. per minute. Where all the conditions are suitable the amount of wear in the working parts is very small, and the units are totally enclosed. The system appears to be ideal where all the essential points in the design have been taken care of and the installation is correctly laid out. Generally, the system is more costly than any other system, but the rate of wear and the power required for operation are the lowest, and it is perfectly dust-tight. Experience indicates that every installation must be considered separately. The same general design is being adapted for elevating, but more experience will be required before the success already attained with the conveyor is obtained with the elevator.

Pneumatic systems are being used very successfully under different conditions. One system, developed on the Continent, operates on the same principle as that described earlier for slurry; there are usually two containers, one in process of filling and the other in process of emptying, each container being used for both duties alternately. The container is filled with cement as it leaves the mill, the valve closed, pressure-air turned on, and the cement impelled or transported to the silo or other storage; the valves are then reversed and the process repeated for the other container. The system is in use for transporting several hundred feet horizontally and for heights of over 100 ft. The valves are all arranged for automatic control and, when everything is in order, the equipment works well. Any change in the quantity of the mill output results in a change in time of the transport cycle. There is no minimum limit to the rate of transport for any installation as a reduced mill output only results in an increase of the time between the successive cycles; there is, however, a limit to the higher rate of transport, and the highest probable rate should be arranged for when the plant is installed. The finer the cement the more suitable it is for transport by this system.

Another system, developed in the United States, works without containers, but has a high-speed spiral which feeds the cement into the pipeline. An air chamber is placed at the entrance of the pipeline, and this chamber (with nozzles) facilitates the admission of the pressure air which carries the cement forward. The diagram (*Fig.* 2) shows a section through a Fuller-Kinyon pump, which is the main group unit; A is the collector spiral; B the pump hopper; C the pump spiral; D the pump barrel; E the non-return valve; F the air chamber with nozzles; and G the pipeline. The material is fed into the hopper, the spiral conveys and delivers it just over the top of the nozzles, and the pressure air then engages with it and impels it into and through the pipeline. A bed of material is kept in the hopper to absorb any pressure air that leaks back past the non-return valve. The spiral rotates at high speed— 1,800 to 1,500 r.p.m. for the smaller sizes and 700 to 600 r.p.m. for the larger sizes. The spiral runs quite free when empty, but requires considerable power when material is being transported.

The capacity of the pipeline may be taken at from $1\frac{1}{2}$ tons to $2\frac{1}{2}$ tons of cement per hour per square inch of the internal area of a pipe of average dimensions; a small pipe may convey rather less and a large pipe rather more. A 5-in. pipe under very good conditions will convey 50 to 60 tons per hour and a 6-in. pipe up to 80 tons per hour. It is possible to operate at lower rates or at slightly higher rates if the line conditions are the best and a liberal air supply is available.

The average quantity of air for good conditions may be assessed at 750 to 850 cu. ft. of free air per ton of cement of average fineness; up to 1,500 cu. ft. per ton are frequently provided for long and difficult lines. The pressure of the air is to some extent determined by the length of the pipe-line and its rating; 20 to 25 lb. per square inch would be satisfactory for short or lightly-rated lines, and the area of the nozzles should ensure good distribution without serious throttling. Working pressures of 35 to 40 lb. per square inch have proved sufficient for lines having a horizontal length of 700 ft. to 800 ft. with a vertical rise of over 100 ft.; even this pressure will not always be required, but should be provided. Apart from the working pressure usual with clear lines, it is necessary to provide a reserve pressure, equal to about twice the working pressure, to facilitate clearing the line if it becomes blocked. If single-stage compressors are used they should have a good reserve for emergency use; two-stage compressors are usually adopted, and the reduced power at which they normally operate ensures more economic running at any pressure. As a general rule a liberal supply of air with good pressure reserve results in the minimum of trouble; a limited supply of air with little pressure reserve invariably results in trouble.

As the density of the cement particle is greater than that of the air the velocity of the cement is lower than that of the air stream, and for this reason the cement particles will not be buoyant or float in the air stream but will tend to lag and fall so that their movement takes the form of a series of jumps. The tendency of the large particles to lag will be greater than that of the smaller particles and the length of jump of the large particles will be less than that of the small particles; the larger particles will therefore require a higher air velocity, and a coarsely-ground cement will require a higher air velocity than more finely-ground cement. It is possible that any drift or blocking that occurs will be comprised largely of the larger-size particles.

Vertical pipelines provide the best conditions for pneumatic conveying, with no tendency to blocking or drift. Horizontal lines give little trouble if proper care is taken. Sloping lines should be avoided, as they usually prove a source of trouble. The arrangement of any pneumatic conveying plant should provide for the minimum number of bends, and where bends are imperative their radius should be as large as practicable. This will reduce the power required by the pump and offer the least obstruction to the flow of the air-cement mixture; it will also keep the rate of "scour" to the lowest possible. The coarsest cement causes more scour and wear than the finer cement, but in any case, if the proportions of the line are correct, the rate of wear should not be a cause of anxiety.

The velocity of the air in the pipeline may vary between 60 and 90 ft. per

second, according to the amount of free air that enters the compressor at atmospheric temperature. Any rise in temperature during compression, or which may be caused by the higher temperature of the cement, is all to the good and will result in a higher velocity figure. The actual velocity may vary through the whole length of the line owing to the falling pressure and the changing temperature ; as the weight of air is only about 3 per cent. to 4 per cent. of the weight of cement, the temperature of the air soon becomes equal to, and remains the same as, that of the cement. It has become the practice to use part of the length of the pipeline as a cooler for reducing the temperature of the cement on its way to the silo by laying part of the pipe in a trench filled with running water ; this has proved quite satisfactory, and enables a temperature drop of up to 100 deg. F. to be obtained.

A total power expenditure of 2 to 3 B.H.P. per ton of cement conveyed may be anticipated for an average line if the plant is correctly designed and is run at its designed capacity. Any reduction in the rate of transport will result in an increase of the basic rate of power used ; in fact this can easily be doubled if the rate is reduced. When all the conditions are favourable, the total cost of conveyance may be as low as 1·75 B.H.P. per ton of cement. The air should be filtered after compression to remove as much of the moisture as practicable and also to trap any lubricant used in the compressor ; moisture may prove very troublesome at the nozzles if it is allowed to exist.

The total power required by the two pneumatic systems appears comparable. Very careful tests would be required to determine which of the two is the lowest, and even then the figure obtained would be of little value because it is seldom possible to run a cement plant at full and consistent output over an extended period. Both systems require dust-exhausting plant at the discharge point. Although the quantity of air is small, it is fully laden with dust and likely to be a source of considerable loss. A cyclone for preliminary separation with bag filters for final separation appear to meet the conditions best and most likely to be economic. It may be necessary to apply a heater to the inlet chamber of the filter to keep the temperature above the dew point, but this can only be determined after the plant is in operation.

The advantages of pneumatic conveying for finely-ground dry materials are too pronounced to need emphasis. Any reasonable height and length of transport can be dealt with with perfect dust-tightness and cleanliness and with the minimum number of wearing parts, and problems which are unsolvable by any other method are dealt with quite easily by it. The cost of power frequently appears high, but that is possibly owing to the cost of power taken by the other systems not having been looked into or examined.

# The Flotation Process at a New Cement Works.

A NEW cement works specially designed to manufacture different types of Portland cement with different chemical compositions has been erected at Northampton, Pennsylvania, by the Universal Atlas Cement Co., and was described by Mr. L. G. Sprague (chief chemist of the company) at a recent meeting of the American Institute of Mining and Metallurgical Engineers. The following notes and the accompanying illustrations are from this paper.

A wide variety of differently proportioned raw materials for cement can be made by the froth flotation system in the new plant, which adjusts mixes by a process of subtraction rather than by addition. Undesirable aluminates and silicates from the available impure limestone deposits are discarded, in preference to adding high-grade limestone from distant sources.

Cement rock is to be ground in two separate closed-circuit grinding units, each having a primary and secondary side. The primary mill is a ball mill, 9ft. 6in. in diameter and 8ft. 8in. long, in closed-circuit with a multizone rake classifier. Coarser particles from the rake classifier return to the feed end of the mill and the finer portion of the primary mill discharge enters a bowl classifier. This is in closed-circuit with the secondary mill, which is the same size as the primary mill. The particle size of this classifier-overflow is regulated largely by the amount of water used. The slurry, overflowing the bowls of both units, contains 85 to 87 per cent. of water and is pumped about 1,000ft. up hill to the cement rock thickener which is 200ft. diameter. The silica and iron ore are ground separately from the cement rock in an 8ft. by 7ft. 8in. ball mill in closed-circuit with a rake and bowl classifier, and the ground sand, or iron ore, is pumped to its own thickener.

Thickened cement rock slurry, containing about 36 per cent. of water, is pumped either to blending tanks or to a turbo-mixer for processing by centrifugal classification and flotation. The clear-water overflow from the thickener is returned to the raw grinding mill by gravity.

The cement rock in the quarry varies from 68 to 76 per cent. $CaCO_3$, averaging about 73 per cent., which is converted into a satisfactory mixture of 75·5 per cent. $CaCO_3$. If it is necessary to add sand or iron, or both, for special compositions, these materials are drawn from their thickeners to separate blending tanks and then added to the cement rock and concentrate in the proper proportion. This plant has seventy-two 66in. flotation cells arranged in four parallel rows, and the final product of flotation, containing about 86 per cent. $CaCO_3$, flows by gravity into a 200-ft. concentrate thickener.

Slurry from the kiln tanks is pumped to the constant level basin of the filters. Each kiln is provided with two slurry-filter units of the rotating disc type. Each unit has nine discs 8ft. 10in. in diameter with a total filtering area of 936 sq. ft. The slurry enters the filters containing about 36 per cent. of water, and the cake discharged from the filters contains about 23 per cent. of water. A motor-driven plunger pump forces the cake into the kiln.

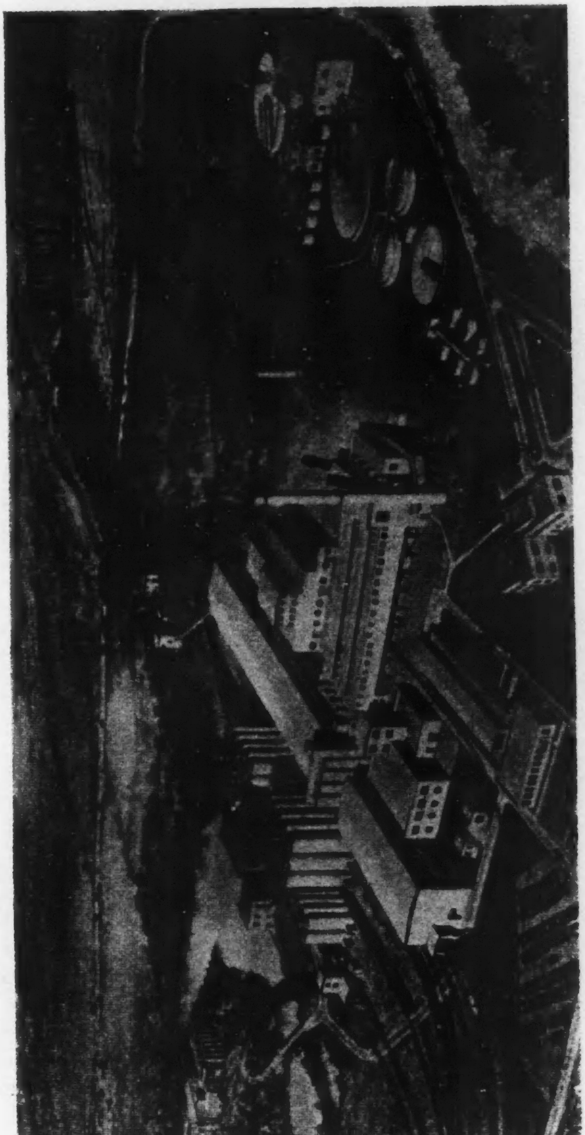


**Fig. 1.—New Cement Works at Northampton, Pennsylvania.**

The plant will have four kilns, three measuring 10ft. 6in. by 250ft. and the other 9ft. by 250ft., of all-welded shell construction, with stiffening rings every 20ft. Each is carried on four box-type rings riding on solid forged rolls, which have water-cooled bronze bearings and are equipped with flood-oil lubrication. The drives will be 125 h.p. adjustable-speed direct-current motors connected to speed reducers. There are two manholes opposite each other and about 75ft. from the discharge ends of the kilns to facilitate the handling of bricks during re-lining. Firing is by direct-firing unit coal mills and the clinker will be cooled in an air-quenching type cooler. It will then be stored in the large storage building ready for handling to the hoppers of the clinker mills.

**Fig. 2.—Secondary Mill, Bowl Classifier, and Rake.**

There are three separate and complete grinding units for clinker, each consisting of a preliminary ball mill and ball-peb mill for finished grinding. Two feeding belts, one for clinker and one for gypsum, deliver the material to a bucket elevator which discharges directly into the preliminator which is a 9ft. 6in. diameter by 8ft. 8in. ball mill. The discharge from this mill is elevated and flows directly into an 8ft. by 30ft. two-compartment ball-peb mill for final grinding. The discharge from this mill is elevated to two air separators, with the coarser portion returning to the mill, and the finished cement delivered by a common screw conveyor to a bin serving a cement pump.

Cement storage comprises two groups of fifteen reinforced concrete silos with eight interstitial bins. The bottoms of the silos are self-cleaning steel hoppers. Under each row of hoppers a cement pump is mounted on a steel truck that can

be moved on rails to receive the cement from any of the bins. Cement can be delivered into steel bins above the packing machines or transferred to other storage bins.

There are four automatic bag-filling and weighing machines. For loading bulk cement there is a separate building, where it is delivered directly into a truck

**Fig. 3.—Centrifuge Machines.**

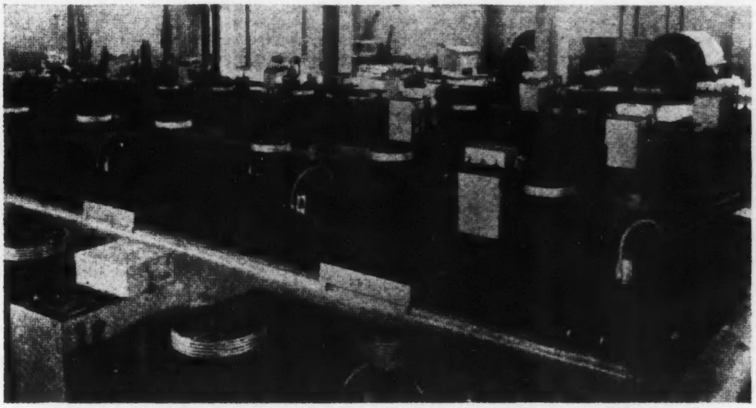


**Fig. 4.—Flotation Cells, with Centrifuge Machines in Background.**

standing on a track scale. Chutes on the sides of each silo in the outside rows can be used for loading bulk cement directly into trucks.

Electric power is generated by two 6,250-k.v.a. three-phase, 60-cycle 2,400-volt generators, each driven by a direct-connected steam turbine operating at 3,600 r.p.m. at 250 lb. per square inch pressure.

# Increasing the Output of Existing Lime Kilns.

Some notes on methods of increasing the output of lime kilns are given by Mr. V. J. Azbe in a recent number of *Rock Products* (November 1942) in view of the need in America as well as in this country to make existing plants as efficient as possible. The author points out that the capacity of some plants can be increased by 50 per cent. by simply closing the kiln tops and putting them under induced draught with a fan. In one plant the capacity was doubled by adding fans, and will be trebled when the re-arrangement programme is complete. The amount of steel used was insignificant compared with what it would have been with new kilns.

Another plant that four months ago was making 30 tons of lime is to-day making 160 tons, and the whole was accomplished at an expenditure of about £8,000. Two old kilns were rearranged and a new kiln built, but the shell was the re-rolled steel of an old tank. Very little new steel or new equipment went into the plant except fire-brick.

Recently some work was done on a 175-ft. rotary kiln. It had no cooler, and normal average capacity was 168 tons. A simple cooler was constructed and on its installation capacity increased to 185 tons, and the fuel ratio was lowered by ½ lb. per ton of lime. Later, by further adjustment, the capacity was raised to over 200 tons. If the sensible heat of the lime is recovered and returned, if kiln rotation of fifty seconds is possible, if the pitch of the kiln is right and an ample amount of stone can be fed, if the pulveriser has the capacity to grind the

coal, and the kiln has the draught to take the gases away, then the upper limit of such a kiln will be close to 250 tons.

The kiln shown in *Fig.* 1 has the least amount of steel and refractory for the amount of shaft area, and the simplest foundation, and can be built at the lowest cost considering its capacity. The 56 sq. ft. shaft should give 50 tons of lime with reasonable size stone; the adjacent gas producer should be instrumental in securing a fuel ratio of 5 to 1. Such kilns could be built quickly and cheaply and new shells would, perhaps, not be necessary.

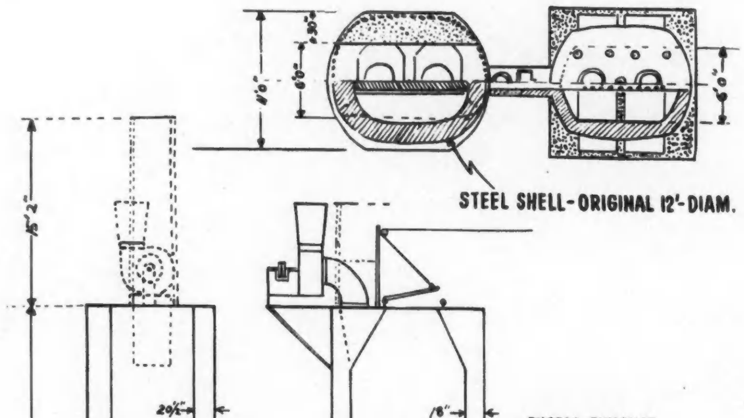



**Fig. 1.—Suggestion for an Economical Lime Kiln.**